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HIGGS SEARCHES AT L3

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Standard and non-minimal Higgs searches were performed with data collected by the L3 detector in e^+e^- collisions at 189 – 202 GeV center-of-mass energies. The standard search methodology is described. An example of non-standard search is reviewed as well and results at the above mentioned center-of-mass energies are presented.

1 Standard Model Higgs searches.

1.1 Introduction.

The Standard Model (SM) provides fermions and gauge bosons masses through electroweak symmetry breaking, the so-called Higgs mechanism¹. Introducing one complex scalar Higgs doublet, the three gauge bosons W^\pm and Z^0 get their longitudinal polarisation, and become massive². It remains one degree of freedom, corresponding to a new fundamental scalar particle, the Higgs boson.

1.2 Production mechanism.

The main process to produce the Higgs boson at LEP2 is the Higgs-Strahlung. The corresponding Feynman diagram is presented below (Fig. 1). An off-shell Z boson is produced, and is decaying into an on-shell Z boson and a Higgs boson.

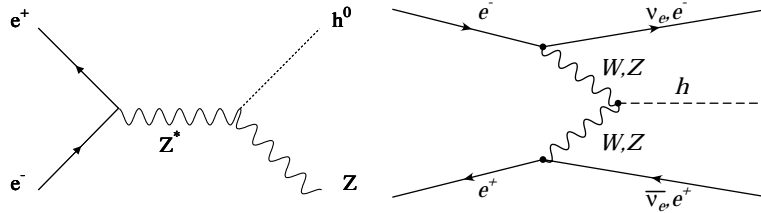


Figure 1. Higgs boson processes : left) Higgs-Strahlung, right) W or Z fusion.

Especially in the missing and the leptonic channels, the Higgs boson can be produced by W or Z fusion (Fig. 1). But the cross section is small compared to Higgs-Strahlung process (Fig. 2).

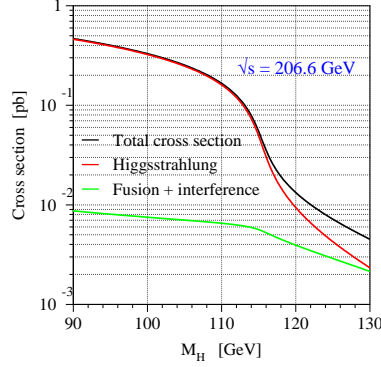


Figure 2. Cross section for Higgs boson production.

1.3 Higgs boson decay.

The coupling between the Higgs boson and the charged fermions is proportional to their masses. In the range of mass of interest, the Higgs boson will decay preferentially into b quarks (Fig. 3). The Z boson branching ratios will determine the different topologies.

1.4 Four topologies.

The Z boson can decay into a pair of quarks (four-jet topology, 65% of the total number of events), or a pair of neutrinos (missins energy channel, 19% of events), or a pair of electrons or muons (leptonic channels, 6% of events). Finally, the Z or the Higgs boson can decay into a pair of taus, and the other particle into a pair of quarks (in this case, we get two jets and two mini-jets from the taus, 9% of events).

1.5 Analysis procedure.

First of all, loose cuts are used to reduce the most copious backgrounds, like the *two-photon* background ($e^+e^- \rightarrow e^+e^-q\bar{q}$). Afterwards, we apply tighter cuts for each specific topology. For instance, we demand two tagged jets in

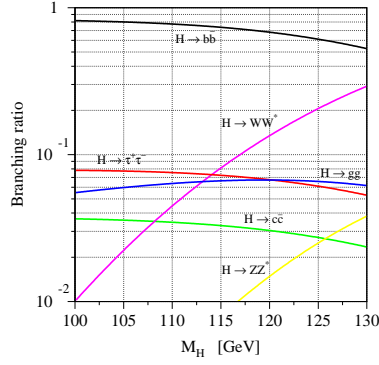


Figure 3. Higgs boson branching ratios.

all topologies as the Higgs boson will decay into $b\bar{b}$. So we are able to build a global variable, which can either be the output of a neural network or a likelihood function. Combining this information with the Higgs mass measurement, we obtain the final discriminant variable (Fig. 4), used to calculate the confidence level (CL) for each mass hypothesis.

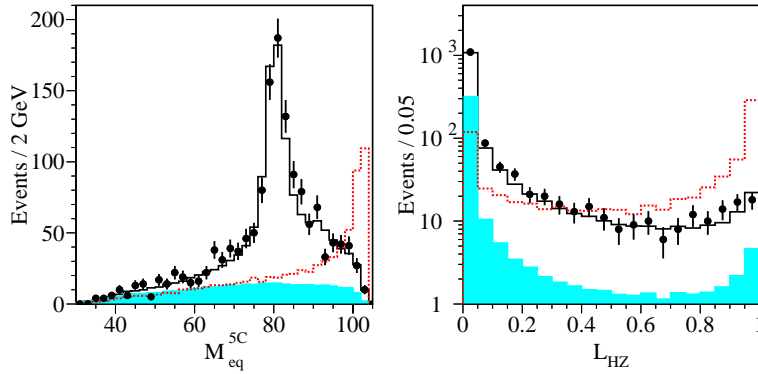


Figure 4. $Hq\bar{q}$ search channel : left) Higgs mass distribution, right) likelihood output.

1.6 Confidence levels.

We construct a statistical estimator (designed here by $-2\ln(Q)$), depending on the Higgs mass hypothesis, so as to test the compatibility of the data with the *signal plus background* hypothesis, or the *background only* hypothesis. This estimator is taken to be :

$$-2\ln(Q(m_H)) = 2s_{tot} - 2 \sum N_i \cdot \ln[1 + s_i(m_H)/b_i] \quad (1)$$

where m_H is the Higgs mass hypothesis, s_i and b_i the expected signal and background numbers of events respectively. N_i takes the values of d_i (data), b_i or $s_i + b_i$ following the hypothesis. By integrating the $-2\ln(Q)$ distributions, we can obtain :

- the $(1 - CL_b)$ (Fig. 5) representing the compatibility between the data and the SM background expectations.
- the CL_s (Fig. 5) which allows us to set a limit.

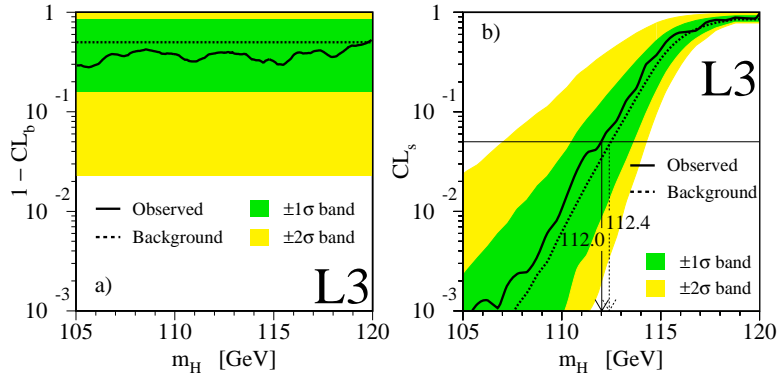


Figure 5. Confidence levels.

The observed lower limit on m_H is 112.0 GeV at the 95% CL, while the expected lower limit is 112.4 GeV³. For $m_H = 115$ GeV, the background probability ($1 - CL_b$) is 32%. Preliminary combined searches from the four LEP experiments, Aleph, Delphi, Opal and L3 give an observed lower bound on its mass at a 95% CL⁴: $m_H > 114.1$ GeV. On the other hand, precision measurements of electroweak observables, which involve virtual Higgs boson exchanges, give an upper bound of⁵: $m_H < 210$ GeV at a 95% CL.

2 Beyond Standard Model Higgs searches.

2.1 Two Higgs doublet models of type II

In general two Higgs doublet models of type II ², five scalar Higgs bosons appear after symmetry breaking. Both searches for the production of the h and A Higgs bosons in the processes $e^+e^- \rightarrow hZ$ and $e^+e^- \rightarrow hA$ are used. We did not use any b-tagging in order to perform a flavour-independent search, since the coupling of the Higgs boson to the b quarks could be suppressed.

The dominant production mechanisms are the following :

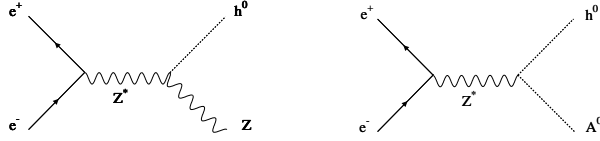


Figure 6. hZ and hA processes

The cross sections can be parametrized as a function of the Standard Model (SM) cross sections as :

$$\sigma_{hZ} = \rho \cdot \sigma_{hZ}^{SM} \quad (2)$$

$$\sigma_{hA} = \eta \cdot \lambda \cdot \sigma_{hZ}^{SM} \quad (3)$$

where σ_{hZ}^{SM} is the cross section for $e^+e^- \rightarrow hZ$ in the SM, ρ and η are the couplings, to the Z normalized to the SM ones

$$\rho = \frac{g_{hZZ}^2}{(g_{hZZ}^{SM})^2} \quad (4)$$

$$\eta = \frac{g_{hAZ}^2}{(g_{hZZ}^{SM})^2} \quad (5)$$

and λ is a phase space factor.

2.2 One example : the search for $h, A \rightarrow q\bar{q}\tau^+\tau^-$

We give the result for a search of the process $h, A \rightarrow q\bar{q}\tau^+\tau^-$, with an upper limit on the η parameter (Fig. 7). The analysis procedure is the same as that described in Ref. ⁶.

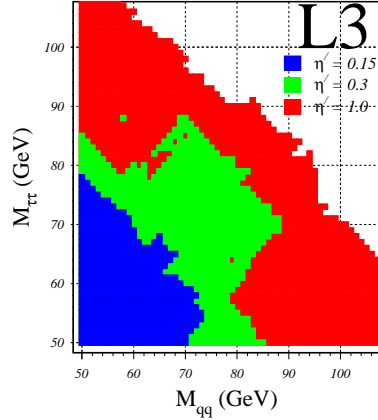


Figure 7. Upper limit on the η parameter.

3 Conclusion.

There was an excellent LEP performance in 2000 : \sqrt{s} up to 209 GeV, and more than 200 pb^{-1} of integrated luminosity collected per experiment. The observed lower bound on SM Higgs boson found by L3 is 112.0 GeV. Other results concerning flavour-independent analyses and Minimal Supersymmetric Standard Model searches can be found in : <http://l3www.cern.ch/conferences/contributions.html>

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